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(54) **SYSTEMS AND METHODS EMULATING
AUTOMOBILE MOVEMENT**

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See application file for complete search history.

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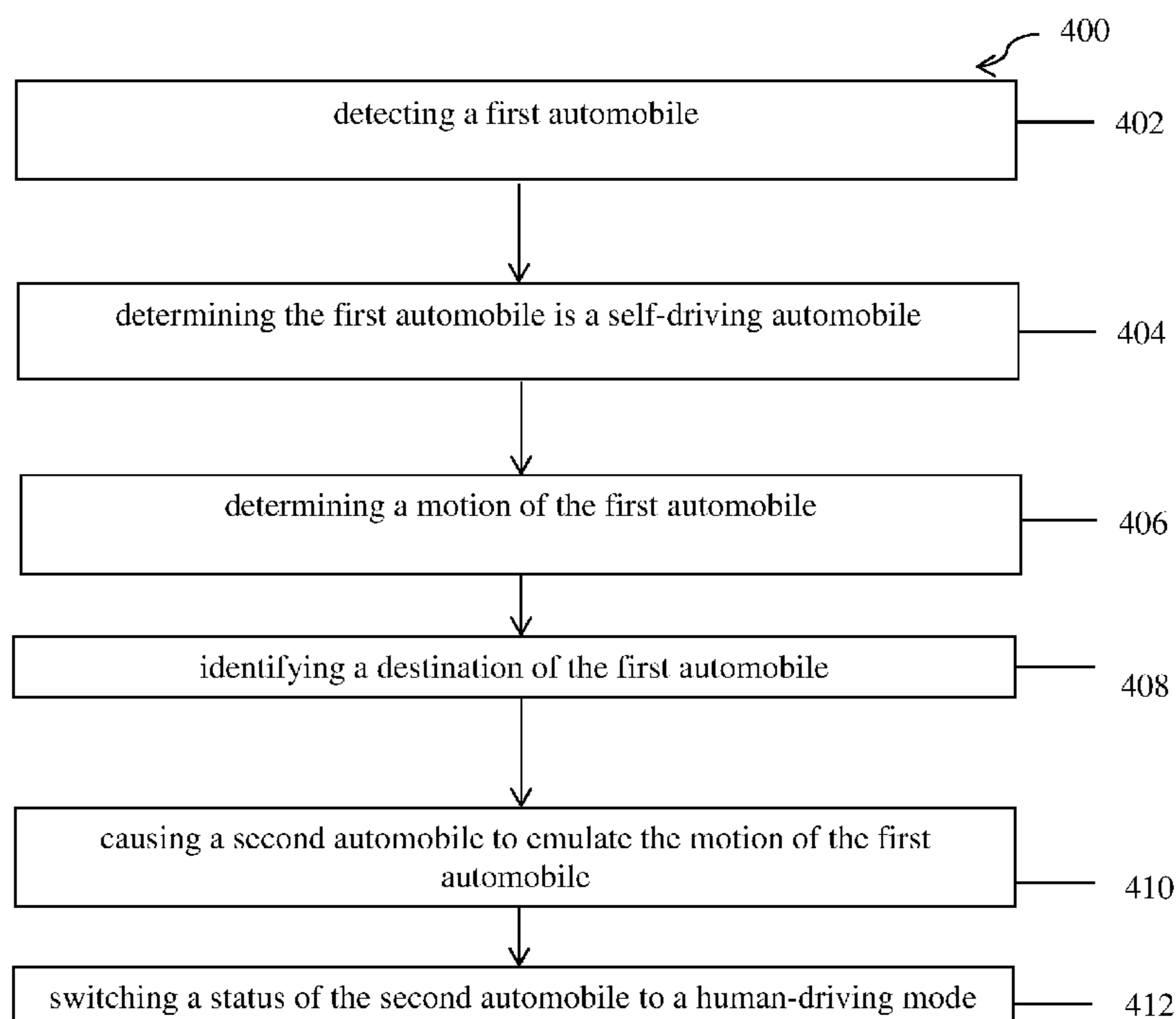
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(57) **ABSTRACT**

A system, including: a non-transitory memory; and one or more hardware processors coupled to the non-transitory memory and configured to read instructions from the non-transitory memory to cause the system to perform operations including: detecting a first automobile; determining that the first automobile is a self-driving automobile; and in response to determining that the first automobile is a self-driving automobile, causing a second automobile to emulate a motion of the first automobile.

20 Claims, 5 Drawing Sheets



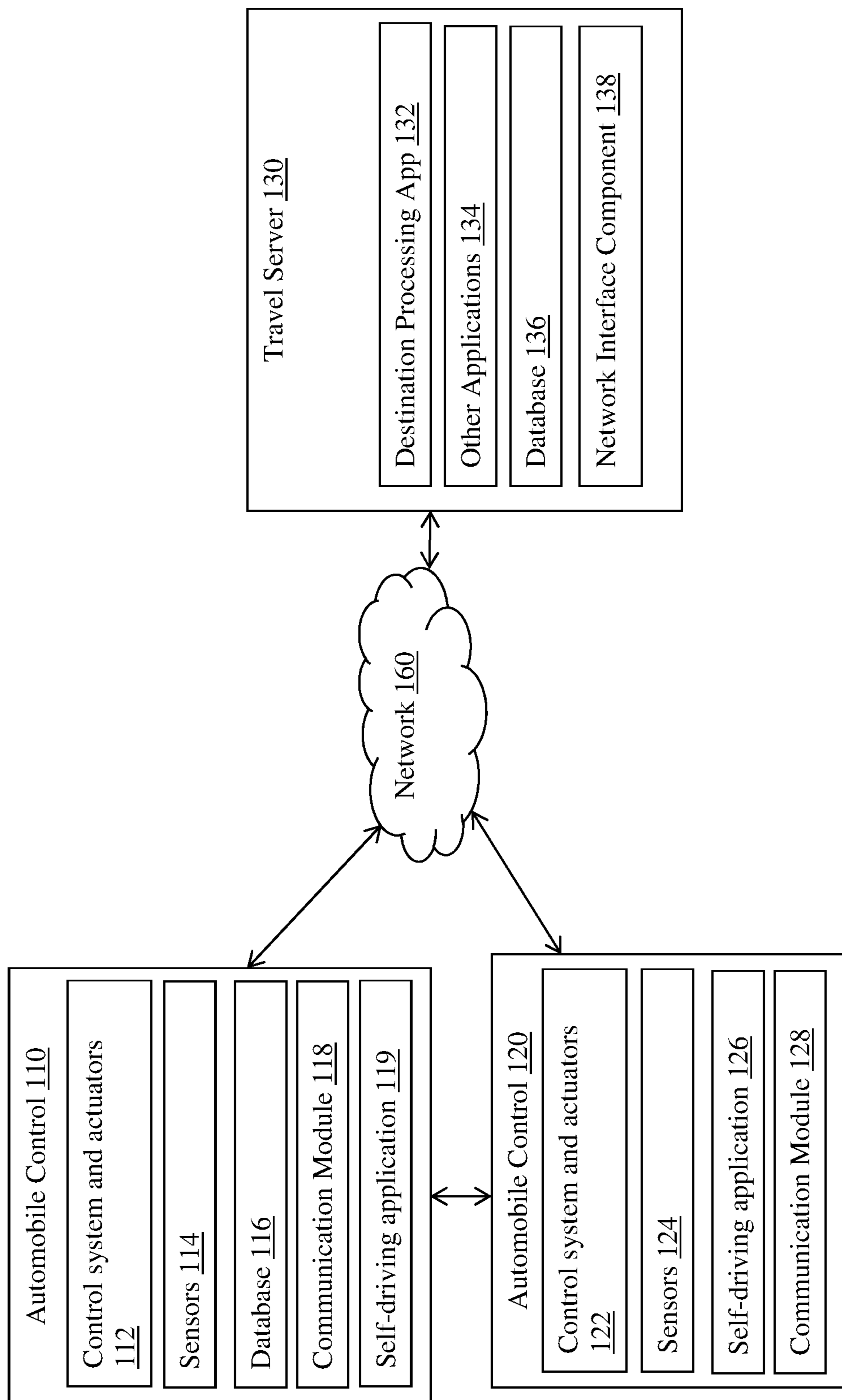


Fig. 1

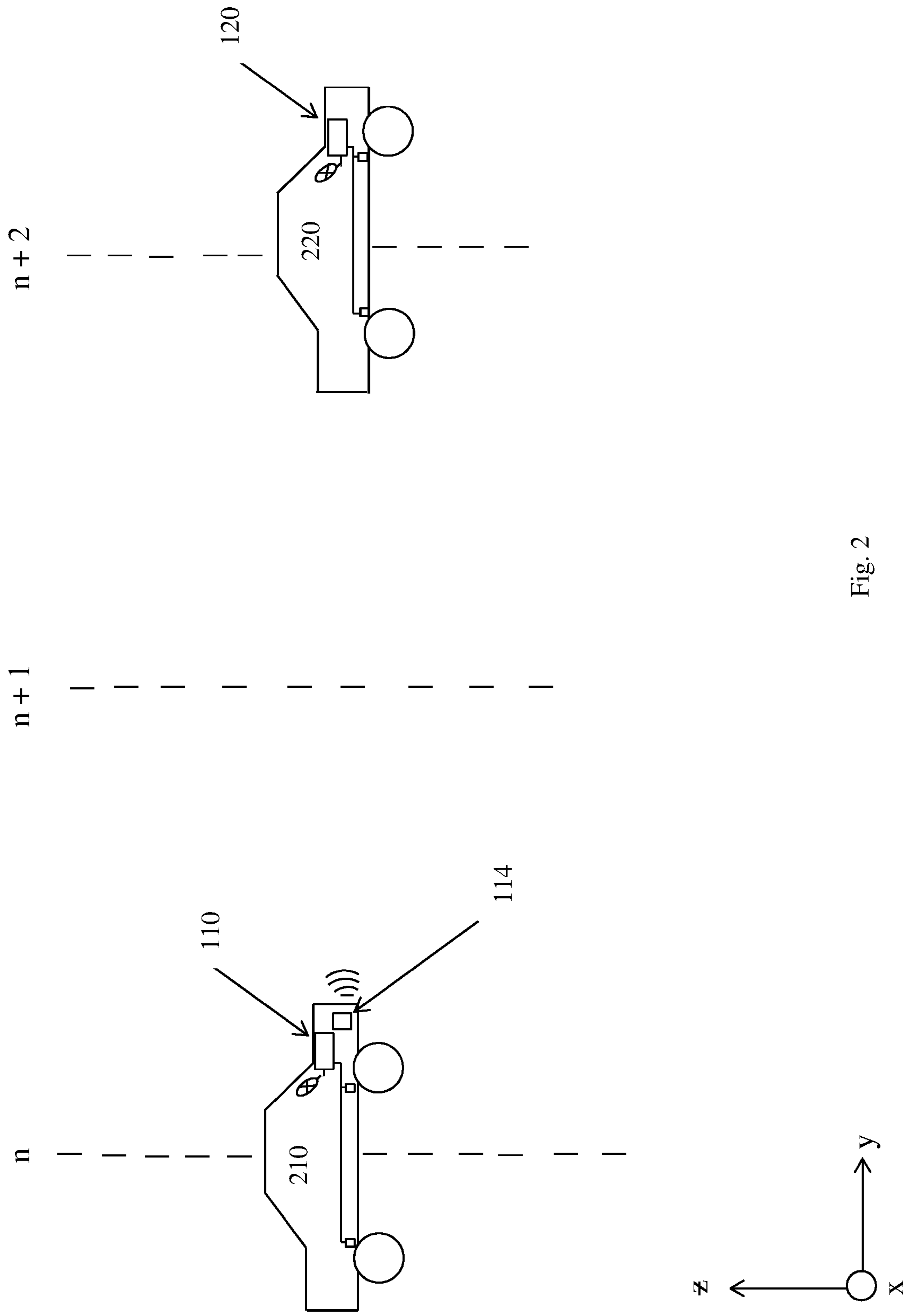


Fig. 2

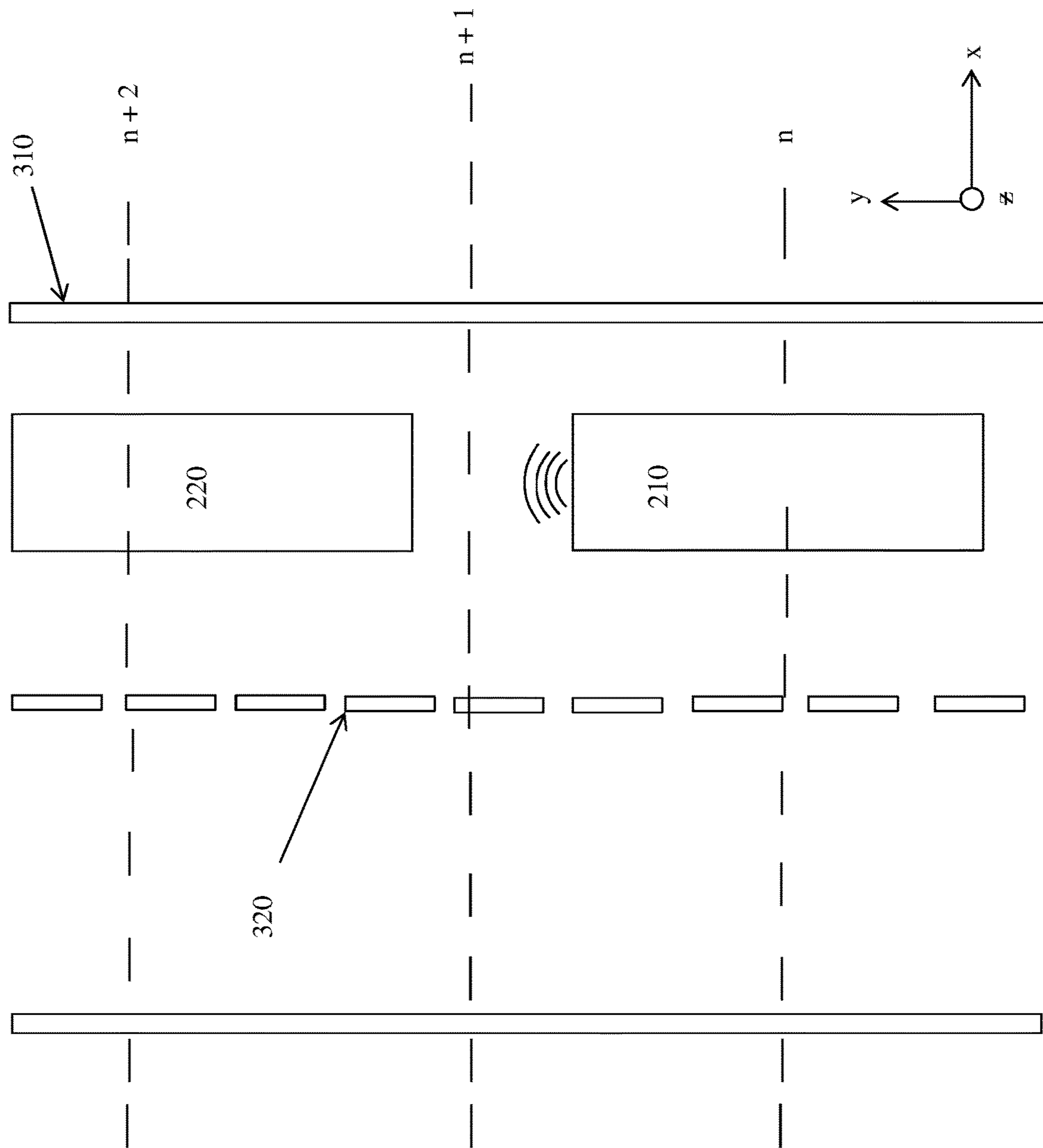


Fig. 3

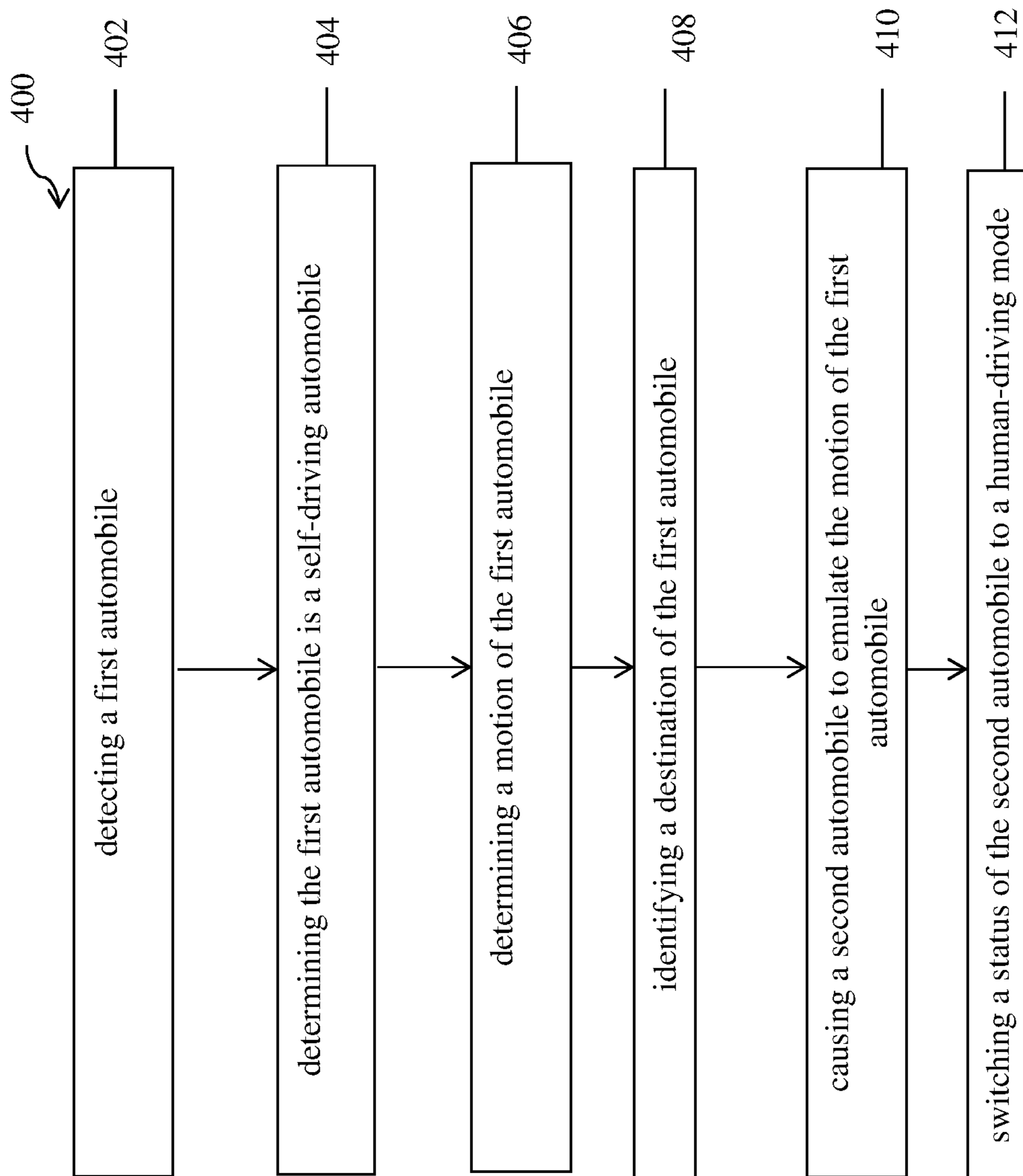


Fig. 4

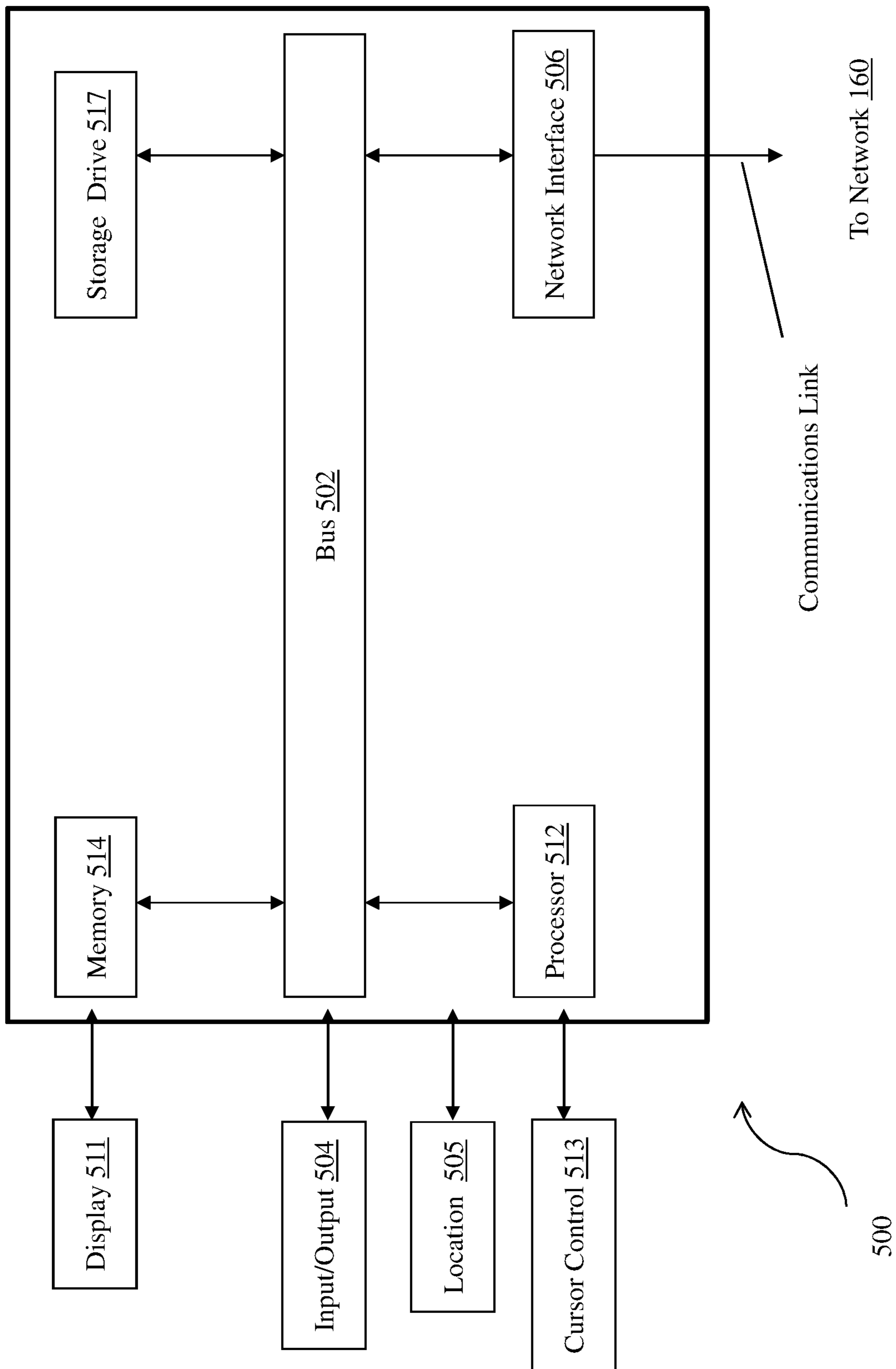


Fig. 5

1**SYSTEMS AND METHODS EMULATING
AUTOMOBILE MOVEMENT****BACKGROUND**

Field of the Disclosure

The present disclosure generally relates to automated automobile movement, and more particularly to systems and methods identifying self-driving automobiles and emulating the movements of self-driving automobiles.

Related Art

Automation is increasing as computing power gets cheaper and more ubiquitous. Examples include increasing use of robotics in manufacturing and surgery, but also in areas that are touched by consumers. For instance, digital personal assistants and home automation hubs are beginning to be commonplace in consumer homes, allowing users to control devices in their homes and to call up information with voice commands.

An example of increasing automation includes self-driving automobiles, which are becoming more sophisticated each year. For instance, some automobiles provide partial self-driving capabilities, including allowing a user to take her hands off of the steering wheel while software intelligence within the car reads lane markers and keeps the car safely within its own lane as it moves forward. Partial self-driving capabilities are usually implemented for short periods of time, requiring a user to place her hands back on a steering wheel after a certain amount of time or when ability to stay within the lane is compromised.

Other automobiles may provide for full or nearly full autonomous driving, even dispensing with a human driver altogether. Whether partially autonomous or fully autonomous, self-driving automobiles tend to rely on a multitude of sensors and sophisticated software. Currently implemented autonomous automobiles may be expected to include a full complement of sensors front, side, and rear to provide comprehensive data regarding the automobile's surroundings, such as other automobiles and obstacles. Such sensors and sophisticated software may be quite expensive, increasing the cost of autonomous features in automobiles beyond a cost that would be expected for non-autonomous automobiles.

Furthermore, as the number of fully autonomous and partially autonomous automobiles increases, they will make up a significant proportion of traffic, while at the same time sharing the road with human-driven automobiles. As the number of cars with various levels of self-driving ability enter the world's roadways, they will continue to interact with each other during the normal flow of traffic and attempt to avoid or minimize collisions whether by human command or autonomously.

Thus, there is a need for systems and methods capable of providing cost effective performance while allowing autonomous automobiles to share the road with automobiles of any autonomous ability.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is an illustration of an electronic system, including multiple components communicatively coupled via a network, according to one embodiment;

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FIG. 2 is a schematic diagram of one automobile following another automobile by emulation, according to one embodiment;

FIG. 2 is a schematic diagram of one automobile following another automobile by emulation, according to one embodiment;

FIG. 4 is an illustration of an example method for emulating motion of an automobile, according to one embodiment;

FIG. 5 is an illustration of an example computer system that may be used as an automobile controller or a server and to perform the actions described with respect to FIGS. 1-4, according to one embodiment.

Embodiments of the present disclosure and their advantages are best understood by referring to the detailed description that follows. It should be appreciated that like reference numerals are used to identify like elements illustrated in one or more of the figures, wherein showings therein are for purposes of illustrating embodiments of the present disclosure and not for purposes of limiting the same.

DETAILED DESCRIPTION

The present disclosure describes systems and methods for identifying autonomous automobiles. For instance, a first automobile may include sensors and software configured to determine whether an autonomous automobile is present or proximate the first automobile. An example includes the first automobile observing a driving characteristic of another automobile. The characteristic may include consistency of following distance (e.g., within a +/- predetermined distance from the other automobile), consistency of speed (e.g., the other automobile moving within a +/- rate of travel), conformance to traffic rules (e.g., the other automobile traveling no more than a predetermined number over posted speed limits), consistency of lane position (e.g., the other automobile staying within a lane or not moving laterally within the lane by more than a predetermined amount), which lane the other automobile is driving in, and/or the like. The first automobile may include forward-facing radar or mobile laser scanning (e.g., lidar) that emits electromagnetic radiation and detects reflected electromagnetic radiation and processing hardware and software to process the reflected electromagnetic radiation to discern the driving characteristics. The first automobile uses its radar or mobile laser scanning to scan other automobiles on the road and determine their driving characteristics.

Processing features then compare detected driving characteristics to a plurality of stored driving characteristics in a database or other data structure, including cloud storage. The stored driving characteristics may include values for driving characteristics that indicate the possibility of a self-driving automobile. In response to comparing detected driving characteristics to the stored driving characteristics, the processing features determine that the detected driving characteristic conforms to one or more characteristics of the stored driving characteristics, thereby matching or approximately matching a profile of a self-driving automobile.

In another example, the first automobile includes transducers to detect electromagnetic emissions from other automobiles and processing features to process detections of those emissions. Continuing with the example, various self-driving automobiles may emit one or more characteristic electromagnetic signals. For instance, some may include electromagnetic beacons to specifically identify them as self-driving automobiles. Other self-driving automobiles may emit electromagnetic radiation that incidentally identi-

fies them as self-driving automobiles (e.g., radar or lidar emissions known to be associated with particular makes and models of cars). The first automobile may detect such electromagnetic signals and determine that a particular nearby automobile is a self-driving automobile.

Other examples for identifying automobiles as self-driving automobiles may include receiving an identifier from the automobile and determining the identifier is associated with a self-driving automobile, such as the first automobile scanning license plates and matching license plate data with known self-driving automobiles, such as through accessing DMV sites or other available sites or resources, using computing vision to identify contours and/or badges of automobiles and match them against known self-driving automobile makes and models. In fact, various embodiments may include any appropriate technique to identify self-driving automobiles.

Further continuing with the example, after having identified a self-driving automobile, the first automobile is caused to emulate the motion of the self-driving automobile, thereby allowing the first automobile to follow the self-driving automobile. In an example use case, the first automobile may include processing logic to calculate a speed and a position of the self-driving automobile as the self-driving automobile is in motion for a plurality of discrete locations along a driving path. The first automobile may use radar, lidar, computer vision, and/or the like to track the speed of the self-driving automobile and track the lane position of the self-driving automobile. Furthermore, the first automobile may process data from radar, lidar, computer vision and/or the like to create a three-dimensional model having a plurality of time slices, where each of the time slices is associated with a speed value and a location value for the self-driving automobile, wherein a location value may include a lane position and a relative position with respect to the self-driving automobile.

The first automobile then conforms to the speed and position of the self-driving automobile in real-time as the first automobile follows the self-driving automobile along the plurality of discrete locations of a driving path. For example, processing logic at the first automobile may send signals to various actuators within the first automobile to cause those sensors and actuators to adjust steering, braking, throttle, and/or the like to conform to the speed and position of the self-driving automobile.

In another example, processing logic identifies a destination of the first automobile and of the self-driving automobile, compares the destinations, and upon determining that the destinations are the same or similar, causing the first automobile to emulate the motion of the self-driving automobile in order to bring the first automobile to the destination. To a human observer, it would appear that the first automobile follows the self-driving automobile.

Of course, it may be appropriate at a point to switch from an emulation mode to a human-driving mode for the first automobile. Examples include when the first automobile may lose sight of the self-driving automobile, at the direction of the human user, upon detection of possible unsafe conditions, and/or the like. The first automobile may use various warnings, such as flashing lights or haptic warnings, to alert the human driver to take control of the steering, brakes, and throttle.

Various embodiments may include physical systems to implement emulation of motion of a self-driving automobile, including radar, lidar, vision hardware, hardware and software to process information (e.g., motion data) from the radar, lidar, vision, and a control system to determine

specific control signals for actuators in response to the processed information. Various other embodiments may include methods to perform the emulation. Other embodiments may include non-transitory machine-readable media storing machine-readable instructions executable to provide functionality as described herein.

Various embodiments may include one or more advantages over conventional systems. For instance, in a use case in which the first automobile (the following automobile) is not fully self-driving, it may nevertheless be able to emulate an identified self-driving automobile, thereby allowing the driver of the first automobile to experience benefits of self-driving. Furthermore, in various embodiments the first automobile may not include as many sensors or software as sophisticated as that of a fully self-driving automobile. For instance, the first automobile may omit sideways facing sensors or rear facing sensors that would otherwise be present in a fully self-driving automobile. However, the first automobile may still be able to perform similarly to a fully self-driving automobile, at least for a period of time and in certain circumstances. Thus, various embodiments may save manufacturing cost relative to a fully self-driving automobile by allowing automobiles with less self-driving capability to emulate automobiles with more self-driving ability. Additionally, allowing the first automobile to follow the self-driving automobile while emulating the self-driving automobile may make traffic flow more efficient and safe by providing a consistent and safe following distance for the first automobile. Thus, another advantage may include more efficient and safe traffic flow as well as a greater cooperation between automobiles of different self-driving abilities.

FIG. 1 is a block diagram of a networked system 100 suitable for implementing the processes described herein, according to an embodiment. As shown, system 100 may comprise or implement a plurality of devices, servers, and/or software components that operate to perform various methodologies in accordance with the described embodiments. Exemplary devices may include specialized automobile control devices, such as digital controller-based systems that perform cruise control, engine control, braking, instrumentation, and the like. Example devices may use hardware, software, and/or firmware executed by a processor (e.g., a digital controller) to provide functionality described herein. Servers may include stand-alone, and enterprise-class servers, operating an OS such as a MICROSOFT® OS, a UNIX® OS, a LINUX® OS, or other suitable device and/or server based OS. It can be appreciated that the devices and/or servers illustrated in FIG. 1 may be deployed in other ways and that the operations performed and/or the services provided by such devices and/or servers may be combined or separated for a given embodiment and may be performed by a greater number or fewer number of devices and/or servers. One or more devices and/or servers may be operated and/or maintained by the same or different entities.

System 100 includes automobile control 110, automobile control 120, and travel server 130, in communication over a network 160. Automobile control 110, automobile control 120, and travel server 130 may each include one or more processors, memories, and other appropriate components for executing instructions such as program code and/or data stored on one or more computer readable media to implement the various applications, data, and steps described herein. For example, such instructions may be stored in one or more computer readable media such as memories or data storage devices internal and/or external to various components of system 100, and/or accessible over network 160.

Automobile control **110** may include a communication module **118** that may utilize appropriate hardware and software configured for wired and/or wireless communication with automobile control **120** and/or travel server **130**. For example, in one embodiment, automobile control **110** may be implemented as one or more digital controller-based devices having access to a cellular data platform, a Wi-Fi platform, or the like. In another example, automobile control **110** may interface with one or more personal devices of a driver or rider and utilize the communications functionality and applications of the personal device. For example, automobile control **110** may interface with a user's personal computer (PC), a smart phone, laptop/tablet computer, wrist-watch with appropriate computer hardware resources, eyeglasses with appropriate computer hardware, other type of wearable computing device, implantable communication devices, and/or other types of computing devices capable of transmitting and/or receiving data, such as an IPAD® from APPLE®. Examples of operating systems for use with automobile control **110** include iOS® OS, Android® OS, and the like. Thus, any of the components **112-119** may include functionality that may be implemented entirely within a first automobile or may be distributed among the first automobile, the user's personal device, and/or the travel server **130**.

Automobile control **110** of FIG. 1 includes components such as control system and actuators **112**, sensors **114**, a database **116**, a communication module **118**, and a self-driving application **119**. Components **112-119** may correspond to executable processes, procedures, and/or applications with associated hardware. In other embodiments, automobile control **110** may include additional or different modules having specialized hardware and/or software as required.

Control system and actuators **112** may correspond to one or more hardware devices and associated processes to operate a first automobile through controlling operations such as engine function, braking function, steering function, instrumentation, infotainment, navigation, and the like. In various embodiments, control system and actuators **112** may include an engine control unit (ECU), which monitors items such as fuel/air mixture, revolutions per minute, and the like and uses actuators (not shown) to physically implement and adjust those items. Also in various embodiments, control system and actuators **112** may include a braking control unit, which monitors traction conditions and breaking commands and actuates calipers or other breaking hardware to cause the first automobile to slow down, stop, distribute torque among wheels, and the like. Various embodiments of control system and actuators **112** may also include a steering control unit, which may be a drive-by-wire unit, a hydraulically assisted unit, or other steering unit that physically changes the direction of at least the front wheels of the automobile according to user commands or other commands.

Of course, those are examples of automobile functions that may be performed by control system and actuators **112**, but those examples are not intended to be comprehensive. Rather, in other embodiments, additional functions, such as transmission functions, traction control, tire pressure monitoring, hybrid drive functions, and electric drive functions may be assigned to control system and actuators **112**. Furthermore, the scope of embodiments is not limited to an internal combustion automobile, as any automobile drive system now known or later developed may be adapted for use in various embodiments.

Sensors **114** may include any of a variety of devices and computer functionality to determine a speed and position of

an automobile as well as any other automobiles that may be proximate the automobile. For instance, sensors **114** may include a forward-facing sensor system such as radar, lidar, visual light or infrared vision sensors and their associated processing systems. Sensors **114** may emit electromagnetic radiation and receive reflections of that emitted electromagnetic radiation or may simply receive electromagnetic radiation, where examples of electromagnetic radiation include radio signals, microwave signals, visible light, infrared light, and/or the like. For instance, radar and lidar may emit radar or lidar signals and then receive reflections of the signals, whereas vision sensors may or may not emit light but in any event receive reflected light. Sensors **114** process the received electromagnetic radiation to determine position and speed of the first automobile as well as objects (e.g., other automobiles) around the first automobile. In one example, the first automobile may use sensors **114** to calculate the speed and position of another automobile as that other automobile is in motion along a driving path of that other automobile.

In an example embodiment, sensors **114** may read license plate data of other automobiles, read badging of other automobiles, or discern contours of other automobiles to visually identify a make and model of other automobiles, and/or the like. Continuing with the example embodiment, sensors **114** may also receive electromagnetic signals from other automobiles, such as communication signals that identify those other automobiles or other emissions such as radar emissions. Sensors **114** may be in communication with control system and actuators **112**, database **116**, communications module **118**, and self-driving application **119** via a bus or network as appropriate.

In various embodiments, automobile control **110** includes self-driving application **119** as may be desired in particular embodiments to provide full or partial self-driving abilities. For instance, self-driving application **119** may include hardware and/or software functionality to communicate with control system and actuators **112** to steer the first automobile and control the speed of the first automobile according to one or more driving algorithms that may be fully or almost fully automated or may include some combination of automation and human-based driving. In one example, self-driving application **119** uses information from sensors **114** to map speed and position of another automobile over a plurality of discrete locations and then provide signals to control system and actuators **112** to emulate the speed and position of the other automobile. Furthermore, self-driving application **119** may include location detection applications, such as a mapping, compass, and/or GPS applications, which may be used to determine a physical location for the automobile.

Self-driving application **119** may further include social networking applications and/or travel applications. For instance, self-driving application **119** may communicate via module **118** (and perhaps network **160**) with automobile control **120** and travel server **130** to identify destinations of other automobiles, compare destinations of the other automobiles to the destination of the first automobile, and to emulate the movement of another automobile in response to determining a same destination. In this embodiment, self-driving application **119** may include a social media component to disclose and receive travel information from other users. Self-driving application **119** may include device interfaces and other display modules that may receive input and/or output information. For example, self-driving application **119** may contain software programs, executable by a

processor, including a graphical user interface (GUI) configured to provide an interface to a driver by a display screen in the first automobile.

Automobile control **110** may further include database **116** stored to a memory of automobile control **110**, which may store various applications and data and be utilized during execution of various modules of automobile control **110**. Thus, database **116** may include, for example, IDs such as operating system registry entries, IDs associated with hardware of automobile control **110**, entries including stored driving characteristics associated with self-driving automobiles, destination information, user profile information, and the like. Self-driving application **119** may access database **116** and use data, such as stored driving characteristics, to compare driving characteristics of other automobiles on the road to those stored driving characteristics and to determine that one or more other automobiles are self-driving automobiles by making a match or a near match between observed driving characteristics and one or more stored driving characteristics.

For instance, an exact match of driving characteristics may not be used in some embodiments, as observed characteristics may be weighted and applied in an algorithm to determine whether it is more likely than not that and other automobiles a self-driving automobile. For instance, various algorithms may include threshold parameters that may be met by correlating observed driving characteristics to stored driving characteristics and weighting the correlation numbers and then comparing weighted correlation numbers or sums to one or more threshold parameters. In other embodiments, artificial intelligence and self-learning algorithms may be used to identify other self-driving automobiles using any useful data stored to database **116**.

Database **116** may also include historical location information of the user, historical destination information of the user, and may include pre-programmed map data. Self-driving application **119** may access database **116** and use such information to provide navigation services and useful information to a user on a display within the automobile.

Automobile control **110** includes at least one communication module **118** adapted to communicate with automobile control **120** and/or travel server **130**. In various embodiments, communication module **118** may include a broadband device, a satellite device and/or various other types of wired and/or wireless network communication devices including microwave, radio frequency, infrared, Bluetooth, and NFC devices.

Automobile control **120** may be included in an additional automobile that shares the road with the automobile associated with automobile control **110**. In other words, automobile control **110** automobile control **120** may be associated with two different automobiles in motion and sharing the road concurrently. Automobile control **120** may be implemented using hardware and/or software, the same as or similar to that described above with respect to automobile control **110**.

Control system and actuators **122** may be implemented within the other automobile the same as or similar to control system and actuators **112** are implemented within the automobile associated with automobile control **110**. Control system and actuators **122** may also perform the same or similar functions as those described above with respect to control system and actuators **112**.

Sensors **124** may be implemented within the other automobile the same as or similar to sensors **114** are implemented within the automobile associated with automobile

control **110**. Also, sensors **124** may perform the same or similar functions as those described above with respect to sensors **114**.

Communication module **128** may be implemented within the other automobile the same as or similar to communication module **118** is implemented within the automobile associated with automobile control **110**. Communication module **128** may also perform the same or similar functions as those described above with respect to communication module **118**. Furthermore, automobile control **120** may include other components, such as a database (not shown) the same as or similar to database **116**.

Self-driving application **126** may include a more sophisticated and more robust suite of self-driving logic and hardware than is included with self-driving application **119**. For instance, self-driving application **126** in this example may include more sensors **124** at front, side, and rear to provide a more comprehensive view of surroundings of the automobile associated with automobile control **120**. In other embodiments, self-driving application **126** and sensors **124** may be the same as or similar to self-driving application **119** and sensors **114**. However, an example use case includes the self-driving application **126** and sensors **124** being quite robust and providing fully-autonomous or nearly-autonomous operation during normal driving, whereas the example use case also includes self-driving application **119** and sensors **114** being less advanced. Thus, self-driving application **119** and sensors **114** may be used to emulate the operation of the automobile associated with automobile control **120** in order to provide benefits of more advanced autonomous operation to the less costly system at automobile control **110**.

Travel server **130** may be maintained, for example, by an online or mobile service provider, which may provide information to either or both of automobile control **110** and automobile control **120** and may even in some aspects be used to provide cloud-based processing functionality and data storage that would otherwise be the responsibility of automobile control **110** or automobile control **120**. In this regard, travel server **130** includes one or more processing applications which may be configured to interact with automobile control **110**, automobile control **120**, and/or another device/server to facilitate self-driving.

Travel server **130** of FIG. 1 includes a destination processing application **132**, other applications **134**, a database **136**, and a network interface component **138**. Destination processing application **132** and other applications **134** may correspond to executable processes, procedures, and/or applications with associated hardware. In other embodiments, travel server **130** may include additional or different modules having specialized hardware and/or software as required.

Destination processing application **132** may correspond to one or more processes to track destinations of automobiles, provide navigation services to automobiles, and the like. For instance, in one embodiment, destination processing application **132** may compare locations of various automobiles and send a notification to self-driving application **119** when determining that the automobile associated with self-driving application **126** has a same destination. Furthermore, self-driving application **119** and self-driving application **126** may communicate over network **160** to destination processing application **132** to coordinate destinations or any other useful travel functions. Additionally, automobile control **110** and automobile control **120** may communicate with each other via network **160** and/or directly using some other kind of connection, such as Bluetooth or Wi-Fi.

In one example, other applications **134** includes a social media component, allowing self-driving application **119** and self-driving application **126** to communicate with each other based on linked attributes at the social media component. Other applications **134** may provide additional utility, such as automobile diagnostics and the like. Other applications **134** may contain software programs, executable by a processor, including a graphical user interface (GUI), configured to provide an interface to the user when accessing travel server **130**. In various embodiments where not provided by destination processing application **132**, other applications **134** may include connection and/or communication applications, which may be utilized to communicate information to over network **160**.

Additionally, travel server **130** includes database **136**. Database **136** may include any information needed to detect and/or emulate or improve the detection and/or emulation of self-driving automobiles, such as for example social network identifications, automobile identifications, mapping and navigation data, etc. Furthermore, database **136** may also include user destination history information for a multitude of users, including the user at automobile control **110**, the user at automobile control **120**, user location history, and identifying information for self-driving automobiles, such as by license plate number, make and model, and visual identification indicators correlated to makes and models.

In various embodiments, travel server **130** includes at least one network interface component **138** adapted to communicate with automobile control **110** and/or automobile control **120** over network **160**. In various embodiments, network interface component **138** may comprise a DSL (e.g., Digital Subscriber Line) modem, a PSTN (Public Switched Telephone Network) modem, an Ethernet device, a broadband device, a satellite device and/or various other types of wired and/or wireless network communication devices including microwave, radio frequency (RF), and infrared (IR) communication devices.

Network **160** may be implemented as a single network or a combination of multiple networks. For example, in various embodiments, network **160** may include the Internet or one or more intranets, landline networks, wireless networks, and/or other appropriate types of networks. Thus, network **160** may correspond to small scale communication networks, such as a private or local area network, or a larger scale network, such as a wide area network or the Internet, accessible by the various components of system **100**.

FIGS. **2** and **3** illustrate automobiles **210** and **220**, according to one embodiment and from two different perspectives. Automobile **210** and automobile **220** are both in motion and traveling forward. Specifically, automobile **210** is following automobile **220** along the y-axis. Automobile **210** includes automobile control **110**, and automobile **220** includes automobile control **120**. Automobile control **110** and automobile control **120** are both described above with respect to FIG. **1**, and automobile control **110** and automobile control **120** are implemented in their respective automobiles **210**, **220** to control the operation of those automobiles consistently as described above

Sensor **114** includes forward-facing radar or lidar or computer vision, thereby emitting electromagnetic radiation and then receiving reflected electromagnetic radiation. In one example, automobile control **110** uses the data from sensors **114** to detect the presence of automobile **220** and then to determine that automobile **220** is a self-driving automobile. Determining that automobile **220** is a self-driving automobile may include any of a variety of techniques performed by automobile control **110**. In one

example technique, sensors **114** observe a driving characteristic of the first automobile, such as breaking characteristics, acceleration characteristics, lane placement characteristics, constancy of speed, disciplined observation of driving laws, and the like. Such driving characteristics may be defined by sets of numerical parameters and then correlated with stored driving characteristics (e.g., at database **116**). Appropriate formulas may then be used to generate correlation values and then compare those correlation values to one or more thresholds. Each characteristic may be weighted appropriately, and a correlation score or sum exceeding a threshold may be an indication that automobile **220** is indeed a self-driving automobile. Of course, the scope of embodiments may include using any appropriate driving characteristic and any appropriate threshold and weighting formula. In fact, the scope of embodiments may use any appropriate technique to match observed driving characteristics with known driving characteristics to determine whether a given automobile is a self-driving automobile.

In another example, sensors **114** may read license plate data, e.g., using character recognition and then querying license plate characters over network **160** or with data in database **116** to determine whether a given automobile is a self-driving automobile. For instance, resources (e.g., database **136**) over network **160** or within database **116** may allow referencing license plate data with indications of self-driving abilities for various automobiles. For instance, automobile control **110** may compare license plate data of automobile **220** with stored license plate data and then discern a self-driving status of the first automobile from the comparing. Alternatively, automobile control **110** may generate a query over network **160** to travel server **130**, which then returns a result indicating whether or not automobile **220** is a self-driving automobile. In one embodiment, an identifier of the automobile, such as a license plate or vehicle identification number (VIN), may be detected or obtained, and a database or site, such as managed by the DMV or NHTSA, may be queried or scraped to determine a self-driving level or self-driving type of the automobile, e.g., level 0 to level 5, where current classifications are (generally): Level 0—no self-driving features, Level 1—some driver assistance, Level 2—additional driver assistance, Level 3—conditioned autonomy, Level 4—nearly autonomous, and Level 5—completely autonomous.

In another example, sensors **114** may visually identify a contour of a rear shape of the first automobile from reflected electromagnetic radiation. Automobile control **110** may then compare identified contours against data in database **116** or may generate a query over network **160** to travel server **130** to perform the comparison. Thus, automobile control **110** or travel server **130** may compare identified contours with stored contour data (e.g., database **116** or **136**) to discerning make and model of automobile **220** from the contour and discern a self-driving status of automobile **220** from the make and model. Sensors **114** may additionally or alternatively receive a signal transmitted from automobile **220** and discern a self-driving status of automobile **220** from that signal, wherein some examples the signal may be an identifying signal for make and model or self-driving status. In other examples the signal may be an incidentally identifying signal, such as radar for adaptive cruise control that can be assumed to be associated with self-driving abilities of automobile **220**.

In response to determining that automobile **220** is a self-driving automobile, automobile control **110** causes automobile **210** to emulate the motion of automobile **220**. In one embodiment, the amount or type of emulation is based

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further on determining a level or type of the self-driving automobile, e.g., a Level 5 self-driving automobile may be emulated must closer than a Level 3 self-driving automobile. Continuing with the example, sensor 114 processes the returned electromagnetic radiation to determine speed and position of automobile 220. Additionally or alternatively, sensor 114 may include infrared or visible light image processing to also provide data that can be processed to indicate speed and position of automobile 220. Automobile control 110 uses that data, as described above with respect to FIG. 1, to provide control signals to control system and actuators 112 in order to cause automobile 210 to emulate the motion of automobile 220.

For instance, computer logic of automobile control 110 (e.g., self-driving application 119) uses the data from sensors 114 to generate a three-dimensional model of the position and speed of automobile 220 at a plurality of locations. FIGS. 2 and 3 show example X, Y, and Z axes as well as a plurality of locations n, n+1, n+2. In one example, computer logic of automobile control 110 generates the three-dimensional model by tracking a position of automobile 220 with respect to the right-hand side line 310, a position of automobile 220 with respect to the left-hand side line 320, a distance between automobile 210 and 220, and a speed of automobile 220. Computer logic of automobile control 110 performs these calculations for each of the positions n, n+1, n+2 and stores the results of the calculations in a memory. Though the example of FIGS. 2 and 3 shows only three positions, it is understood that various embodiments may use as many positions as is appropriate. For example, various embodiments may generate a new position every meter, every 10 meters, or other appropriate interval and perform the calculations described above at each of those positions.

Computer logic of automobile control 110 (e.g., self-driving application 119) accesses the position and speed calculations from memory and transforms them into commands that can be issued to control system and actuators 112 to physically cause automobile 210 to emulate the motion of automobile 220. For example, throttle and brake commands may be used to maintain a speed that matches or approximately matches the speed of automobile 220, and steering commands may be used to maintain a lane placement that matches or approximately matches the speed of automobile 220 so that as automobile 210 approaches location n it matches or approximately matches the speed and position that automobile 220 had at that same location. Furthermore, self-driving application 119 uses this calculation to maintain speed, following distance, and lane placement both in straight driving situations and in curved or hilly driving situations. Furthermore, various embodiments may also calculate a z-axis position of automobile 220 to detect hilly driving situations and perform braking or throttle as appropriate.

In curvy driving situations, the three-dimensional model may even continue to follow automobile 220, despite losing straight line of sight with automobile 220 by interpolating three-dimensional placement of automobile 220 from its previous positions and rate of change in the x-axis.

Of course, the drive may eventually come to an end as one or both drivers reach their destinations or decide to part ways. Self-driving application 119 may determine to cease emulating the motion of automobile 220 according to a variety of scenarios. For instance, if it loses line of sight or other communication with automobile 224 longer than a set time threshold or distance threshold, then self-driving application 119 may alert the human driver and hand control over

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to the human driver. Self-driving application 119 may hand over control to the human driver in other scenarios, such as when it is detected that driving conditions have become hazardous. In other embodiments, a human driver may signal to self-driving application 119 that the human driver desires to return to a human-driving mode. The human driver may signal to the self-driving application 119 in any of a variety of ways including, e.g., a voice command, a touch command, or pressing a button.

In some embodiments self-driving application 119 may use various techniques to predict when to hand control to a human driver in order to alert the driver well in advance. For example 1) by determining the destination of automobile 224 and then further determining that both automobiles are nearing the destination; 2) by analyzing the driving path and determining a curve, road hazard, or the like that is expected to create a situation where line of sight with automobile 224 is lost; 3) by communicating with similar automobiles that have emulation technology and identifying where and why they lost connections with the automobiles they were following.

In other embodiments the automobiles 210 and 220 may communicate with each other, either through travel server 130 or directly to each other using for example Bluetooth or Wi-Fi. Thus in one embodiment lane placement and speed may be shared from automobile 220 to automobile 210, which may be used instead of data from sensors 114 or may be used to supplement the data from sensors 114 in generating the three-dimensional model. In another example, automobile control 120 (automobile 220) may be used to directly control the actuators 112 (automobile 210) in real time using a reliable wireless communication between automobiles.

In yet another example, self-driving applications 119 and 126 may communicate either directly with each other or through travel server 130 to share destination information. In such an example, self-driving application 119 (automobile 210) may emulate the motion of automobile 220 so long as self-driving application 126 (automobile 220) is moving in a desired direction toward the destination of automobile 210. When automobile 220 ceases to move in a desired direction, self-driving application 119 may then either switch to a human-driving mode or communicate with another self-driving automobile proceeding in a desired direction and then emulate the movement of that subsequent self-driving automobile. As noted above, coordination of destinations may be performed using destination processing application 132 of travel server 130 or directly automobile-to-automobile via applications 119, 126 as appropriate in various embodiments.

FIG. 4 is an illustration of an example method 400, adapted according to one embodiment. In the following example, the illustrations are provided with respect to automobile control 110 however, it is to be understood that the actions of method 400 may be performed by automobile control 110, travel server 130, or a combination thereof. The various actions are provided by the devices as a result of executing computer-readable code by one or more processors, wherein the computer-readable code includes instructions. In this example, automobile control 110 is associated with an automobile (e.g., automobile 210 of FIGS. 2 and 3) that is following a first automobile (e.g., automobile 220), and it emulates the motion of the first automobile.

At action 402, automobile control 110 detects a first automobile. In one example, automobile control 110 may receive input from forward-facing radar or lidar to detect the presence of another automobile. However, other embodi-

ments may detect automobiles using any appropriate technique, including receiving electromagnetic signals from other automobiles, receiving input from a social media driving application that tracks other automobiles, and the like.

At action **404**, automobile control **110** determines that the first automobile is a self-driving automobile. In one example, automobile control **110** may observe a driving characteristic of the automobile, wherein examples of driving characteristics include obeying traffic laws, consistency of speed, and consistency of lane position. Such example may assume that self-driving automobiles conform to behavior patterns that may be observed and compared to stored data to determine whether an automobile's driving matches known behavior patterns. Automobile control **110** then may compare the observed driving characteristics to a plurality of stored driving characteristics (e.g., in a database) and based on the comparing, determine that the driving characteristic conforms to one or more stored driving characteristics.

In another example of action **404**, automobile control **110** may receive a signal (e.g., a radio beacon signal) transmitted by the first automobile that either purposefully or incidentally identifies the first automobile as a self-driving automobile. Automobile control **110** may then discern a self-driving status of the first automobile from that signal. Additionally or alternatively, automobile control **110** may compare license plate data of the first automobile to stored license plate data, where the license plate data is referenced in a database with self-driving status. Then based on the comparing, automobile control **110** may discern a self-driving status of the first automobile. Similarly, some example embodiments may identify a rear contour shape of the first automobile, discerning make and model of the first automobile from the contour, and then cross reference the contour to a plurality of stored contours associated with make and model data as well as self-driving status of those makes and models.

At action **406**, automobile control **110** determines a motion of the first automobile. For example, automobile control **110** may use data from forward-facing radar or lidar to determine a speed of the first automobile, a distance between the automobile with automobile control **110** and the first automobile, a position of the first automobile to respect to its lane markers, and the like.

At action **408**, automobile control **110** identifies a destination of the first automobile. For example, automobile control **110** may communicate with an automobile control associated with the first automobile to determine the destination of the first automobile, or it may communicate with travel server **130** for the same purpose. Automobile control **110** may compare the destination of the first automobile to the destination of the automobile that is associated with automobile control **110**. In some instances it may be determined that the first automobile and the second automobile have a same destination. Various embodiments may include identifying the destination of the first automobile as a factor used in deciding to emulate the motion of the first automobile at action **410**.

At action **410**, automobile control **110** causes the second automobile (i.e., the automobile **210** associated with automobile control **110**) to emulate the motion of the first automobile. For instance, action **410** may include calculating a speed and a position of the first automobile as the first automobile is in motion for a plurality of discrete locations along a driving path and then causing the second automobile to conform to the speed and the position of the first automobile as the second automobile follows the first automobile

along the plurality discrete driving locations. An example is shown at FIGS. **2** and **3**, wherein the discrete driving locations are labeled n , $n+1$, $n+2$.

In such an example, automobile control **110** would communicate with sensors and actuators of the second automobile to adjust speed and steering of the second automobile in real-time as it follows the first automobile along the plurality discrete locations. Thus, automobile control **110** would attempt to approximate speed and position of the first automobile (e.g., automobile **220** of FIGS. **2** and **3**) at each of positions n , $n+1$, $n+2$, by the second automobile (e.g., automobile **210**) as it reaches each of the positions n , $n+1$, $n+2$. The scope of embodiments is not limited to exact and precise conformance of speed and position, as approximation within the limits and capabilities of the automobile control **110** and its actuators and sensors in apparent real-time occurs at action **410**. For instance, conformance within a pre-determined percentage of speed or position may be performed at action **410**.

At action **412**, automobile control **110** switches the status of the second automobile to a human-driving mode. For instance, automobile control **110** may switch to a human-driving mode in response to determining that the first automobile is changing direction or destination, that traveling conditions have become unsafe, that the first automobile has left sight of the sensors associated with automobile control **110**, or for any other appropriate reason. The human-driving mode may not be entirely free of autonomous features, though the human-driving mode may be more human-oriented than the emulation mode of action **410**. For instance, the human-driving mode may still employ adaptive cruise control or lane keeping assist, while still accepting human driving input.

The scope of embodiments is not limited to the actions **402-412** of FIG. **4**. Rather, other embodiments may add, omit, rearrange, or modify one or more actions as appropriate. For instance, some embodiments may omit identifying a destination of the first automobile and instead determine to emulate the motion of the first automobile based on other factors, such as a human request, or automatically in response to having followed the first automobile for certain time or distance. Also, automobile control **110** may repeat actions **402-412** as desired on one or more journeys.

Furthermore, various embodiments may offer advantages not provided by conventional systems. For instance, some embodiments may allow the automobile that is following and emulating to enjoy the benefits of self-driving without having the same sophistication of hardware or software. For instance, the following and emulating automobile may omit some sensors to the sides or to the rear or may omit sophisticated hardware functions including traffic sign recognition, etc. Moreover, the actions of FIG. **4** may be used as a semi-autonomous mode in an otherwise fully self-driving automobile in response to hardware or software malfunction or in response to user request.

Referring now to FIG. **5**, an embodiment of a computer system **500** suitable for implementing, for example, the automobile controls **110**, **120**, and travel server **130** of FIG. **1** discussed above. It should be appreciated that other devices used in automobiles or in the cloud discussed above may be implemented as the computer system **500** in a manner as follows.

In accordance with various embodiments of the present disclosure, computer system **500**, such as a automobile control system, computer, and/or a network server, includes a bus **502** or other communication mechanism for communicating information, which interconnects subsystems and

components, such as a processing component **512** (e.g., processor, micro-controller, digital signal processor (DSP), etc.), a system memory component **514** (e.g., RAM) a storage drive component **517** (e.g., solid-state, hard drive, or optical), a network interface component **506** (e.g., wireless card, modem, or Ethernet card), a display component **511** (e.g., a touchscreen, CRT, or LCD), an input/output component **504** (e.g., keyboard, keypad, a touchscreen), a cursor control component **513** (e.g., mouse, pointer, or trackball), and/or a location determination component **505** (e.g., a Global Positioning System (GPS) device as illustrated, a cell tower triangulation device, and/or a variety of other location determination devices known in the art.) In one implementation, the storage drive component **517** may comprise a database having one or more storage drive components.

In accordance with embodiments of the present disclosure, the computer system **500** performs specific operations by the processing component **512** executing one or more sequences of instructions contained in the memory component **514**, such as described herein with respect to FIGS. 1-4 discussed above. Such instructions may be read into the system memory component **514** from another computer readable medium, such as storage drive **517**. In other embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the present disclosure.

Logic may be encoded in a computer readable medium, which may refer to any tangible and non-transitory medium that participates in providing instructions to the processing component **512** for execution. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. In various implementations, non-volatile media includes hard drive or solid state drives, such as the storage drive component **517**, and volatile media includes dynamic memory, such as the system memory component **514**.

Some common forms of computer readable media includes, for example, floppy disk, flexible disk, hard disk, magnetic tape, any other magnetic medium, CD-ROM, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, RAM, PROM, EPROM, FLASH-EPROM, any other memory chip or cartridge, or any other medium from which a computer is adapted to read.

In various embodiments of the present disclosure, execution of instruction sequences to practice the present disclosure may be performed by the computer system **500**. In various other embodiments of the present disclosure, a plurality of the computer systems **500** coupled by a communication link **518** to the network **160** (e.g., such as a LAN, WLAN, PTSN, and/or various other wired or wireless networks, including telecommunications, mobile, and cellular phone networks) may perform instruction sequences to practice the present disclosure in coordination with one another.

The computer system **500** may transmit and receive messages, data, information and instructions, including one or more programs (i.e., application code) through the communication link **518** and the network interface component **506**. The network interface component **506** may include an antenna, either separate or integrated, to enable transmission and reception via the communication link **518**. Received program code may be executed by processing component **512** as received and/or stored in storage drive component **517** or some other non-volatile storage component for execution.

The present disclosure may be implemented using hardware, software, or combinations of hardware and software. Also, where applicable, the various hardware components and/or software components set forth herein may be combined into composite components comprising software, hardware, and/or both without departing from the scope of the present disclosure. Where applicable, the various hardware components and/or software components set forth herein may be separated into sub-components comprising software, hardware, or both without departing from the scope of the present disclosure. In addition, where applicable, it is contemplated that software components may be implemented as hardware components and vice-versa.

Software, in accordance with the present disclosure, such as program code and/or data, may be stored on one or more computer readable mediums. It is also contemplated that software identified herein may be implemented using one or more general purpose or specific purpose computers and/or computer systems, networked and/or otherwise. Where applicable, the ordering of various steps described herein may be changed, combined into composite steps, and/or separated into sub-steps to provide features described herein.

The foregoing disclosure is not intended to limit the present disclosure to the precise forms or particular fields of use disclosed. As such, it is contemplated that various alternate embodiments and/or modifications to the present disclosure, whether explicitly described or implied herein, are possible in light of the disclosure. For example, the above embodiments have focused on payees and payers; however, a payer or consumer can pay, or otherwise interact with any type of recipient, including charities and individuals. The payment does not have to involve a purchase, but may be a loan, a charitable contribution, a gift, etc. Thus, payee as used herein can also include charities, individuals, and any other entity or person receiving a payment from a payer. Having thus described embodiments of the present disclosure, persons of ordinary skill in the art will recognize that changes may be made in form and detail without departing from the scope of the present disclosure. Thus, the present disclosure is limited only by the claims.

What is claimed is:

1. A method comprising:

- receiving a first signal from a first automobile;
- emitting a second signal in a direction of the first automobile using a forward-facing sensor system based on the first signal;
- detecting the first automobile based on a received reflected signal of the second signal;
- determining an identifier of the first automobile based on the received reflected signal of the second signal;
- determining a driving characteristic of the first automobile based on the received reflected signal of the second signal;
- determining the first automobile is a self-driving automobile based on the identifier and the driving characteristic of the first automobile;
- querying for a level of self-driving autonomy of the first automobile using the identifier;
- receiving the level of the self-driving autonomy;
- determining, responsive to the level of the self-driving autonomy, a plurality of speeds and a plurality of positions of the first automobile over a time period based at least in part on one or more further signals from the forward-facing sensor system;
- generating a three-dimensional (3D) model of the plurality of speeds and the plurality of positions of the first

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automobile at a plurality of locations over the time period based on the plurality of speeds and the plurality of positions of the first automobile;

controlling actuators of a second automobile associated with the forward-facing sensor system; and 5

emulating the plurality of speeds and the plurality of positions of the first automobile as the second automobile follows the first automobile along a driving path using the 3D model and the controlled actuators.

2. The method of claim 1, wherein determining the driving characteristic of the first automobile further comprises: 10

comparing the driving characteristic of the first automobile to a plurality of stored driving characteristics; and based on the comparing, determining that the driving characteristic of the first automobile conforms to a first characteristic of the plurality of stored driving characteristics. 15

3. The method of claim 1, wherein emulating the plurality of speeds and the plurality of positions of the first automobile comprises: 20

causing the second automobile to conform to the plurality of speeds and the plurality of positions of the first automobile as the second automobile follows the first automobile along the driving path using the 3D model over the time period. 25

4. The method of claim 3, wherein causing the second automobile to conform to the plurality of speeds and the plurality of positions of the first automobile comprises: 30

adjusting a speed and a steering of the second automobile in real-time during following the first automobile along the driving path over the time period.

5. The method of claim 1, further comprising: 35

after emulating the plurality of speeds and the plurality of positions of the first automobile, switching a status of the second automobile to a human-driving mode.

6. The method of claim 1, wherein receiving the first signal comprises: 40

detecting the first signal comprising an electromagnetic emission from a wireless beacon from the first automobile; and

determining that the first signal indicates that the first automobile is the self-driving automobile.

7. The method of claim 1, further comprising: 45

detecting a safety travelling condition during following of the first automobile along the driving path; and

switching the second automobile to a human-driving mode.

8. A system, comprising: 50

a non-transitory memory; and

one or more hardware processors coupled to the non-transitory memory and configured to read instructions from the non-transitory memory to cause the system to perform operations comprising: 55

detecting a first automobile based on a first signal emitted by the first automobile;

emitting a second signal in a direction of the first automobile using a forward-facing sensor system based on detecting the first signal;

determining an identifier of the first automobile based on a received reflected signal of the second signal; 60

determining that the first automobile is a self-driving automobile of a first type based on the received reflected signal of the second signal and the identifier;

querying for a level of self-driving autonomy of the first automobile using the identifier; 65

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receiving the level of the self-driving autonomy; 70

determining, responsive to the level of the self-driving autonomy, a plurality of speeds and a plurality of positions of the first automobile over a time period based at least in part on one or more further signals from the forward-facing sensor system; 75

generating a three-dimensional (3D) model of the plurality of speeds and the plurality of positions of the first automobile at a plurality of locations over the time period based on the plurality of speeds and the plurality of positions of the first automobile; and 80

causing a second automobile to emulate a motion of the first automobile using the 3D model.

9. The system of claim 8, wherein determining that the first automobile is the self-driving automobile comprises: 85

observing a driving characteristic of the first automobile using the second signal;

comparing the driving characteristic of the first automobile to a plurality of stored driving characteristics; and based on the comparing, determining that the driving characteristic of the first automobile conforms to a first characteristic of the plurality of stored driving characteristics. 90

10. The system of claim 9, wherein the driving characteristic comprises an item selected from a list consisting of: conformance to traffic rules; consistency of speed; and consistency of lane position. 95

11. The system of claim 8, wherein emulating the motion of the first automobile comprises: 100

causing the second automobile to conform to the plurality of speeds and the plurality of positions of the first automobile as the second automobile follows the first automobile along a driving path using the 3D model over the time period.

12. The system of claim 8, wherein the motion of the first automobile is emulated when the level of self-driving autonomy is more autonomous than a second type of the self-driving automobile. 105

13. The system of claim 8, wherein the operations further comprise: 110

identifying a destination of the first automobile; and

comparing the destination of the first automobile to a destination of the second automobile,

wherein emulating the motion of the first automobile is performed in response to determining that the first automobile and the second automobile have a same destination. 115

14. The system of claim 8, wherein the operations further comprise: 120

after emulating the motion of the first automobile, switching a status of the second automobile to a human-driving mode.

15. The system of claim 8, further comprising forward-facing radar or lidar coupled to the one or more hardware processors and configured to provide motion data to the one or more hardware processors, wherein the operations further comprise: 125

processing the motion data to determine the plurality of speeds and the plurality of positions of the first automobile. 130

16. The system of claim 8, wherein the first signal comprises an electromagnetic emission from the first automobile identifying the first automobile as the self-driving automobile, and wherein determining that the first automobile is the self-driving automobile of the first type is further based on the first signal. 135

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17. A non-transitory machine readable medium having stored thereon machine readable instructions executable to cause a machine to perform operations comprising:

detecting a first automobile in response to a first signal from the first automobile;

emitting a second signal in a direction of the first automobile using a forward-facing sensor system based on detecting the first signal;

determining an identifier of the first automobile based on at least one of the detecting or the emitting;

determining a driving characteristic of the first automobile based on a received reflected signal of the second signal;

determining the first automobile is a self-driving automobile of a first type based on the identifier;

querying for a level of self-driving autonomy of the first automobile using the identifier;

receiving the level of the self-driving autonomy;

calculating, responsive to the level of the self-driving autonomy, a plurality of speeds and a plurality of positions of the first automobile over a time period based at least in part on one or more further signals from the forward-facing sensor system;

generating a three-dimensional (3D) model of the plurality of speeds and the plurality of positions of the first automobile at a plurality of locations over the time period based on the plurality of speeds and the plurality of positions of the first automobile;

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switching from a human-driving mode of a second automobile associated with the forward-facing sensor system to a self-driving mode; and

emulating the plurality of speeds and the plurality of positions of the first automobile along a driving path of the first automobile using the 3D model and the self-driving mode.

18. The non-transitory machine readable medium of claim 17, the operations further comprising:

returning to the human-driving mode of the second automobile.

19. The non-transitory machine readable medium of claim 17, wherein emulating the plurality of speeds and the plurality of positions of the first automobile comprises:

causing the second automobile to conform to the plurality of speeds and the plurality of positions of the first automobile as the second automobile follows the first automobile along the driving path using the 3D model over the time period.

20. The non-transitory machine readable medium of claim 17, wherein the first signal comprises an electromagnetic emission from the first automobile identifying the first automobile as the self-driving automobile, and wherein determining that the first automobile is the self-driving automobile of the first type is further based on the first signal.

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